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# Unique Metrology Issues in the Last Mile

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Marc Breton, Chief Metrologist

Daniel Gariépy, Research Scientist

Michel Leblanc, Senior Technical Advisor

Benoît Masson, Senior Product Manager

Bernard Ruchet, Optics Specialist


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Telecommunications Test and Measurement

# Summary

-Introduction

-FTTx T&M requirements:

1. Construction and installation testing
   A. Qualify installed outside plant equipment
      - bidirectional optical loss and optical return loss (ORL)
   B. Characterize the fiber
      - fiber, splices, connectors and splitters
2. Service activation testing and troubleshooting
   - Power of each signal within limits
   - Isolate the source/location of a problem

# Introduction: Underlying Drivers of T&M in FTTx

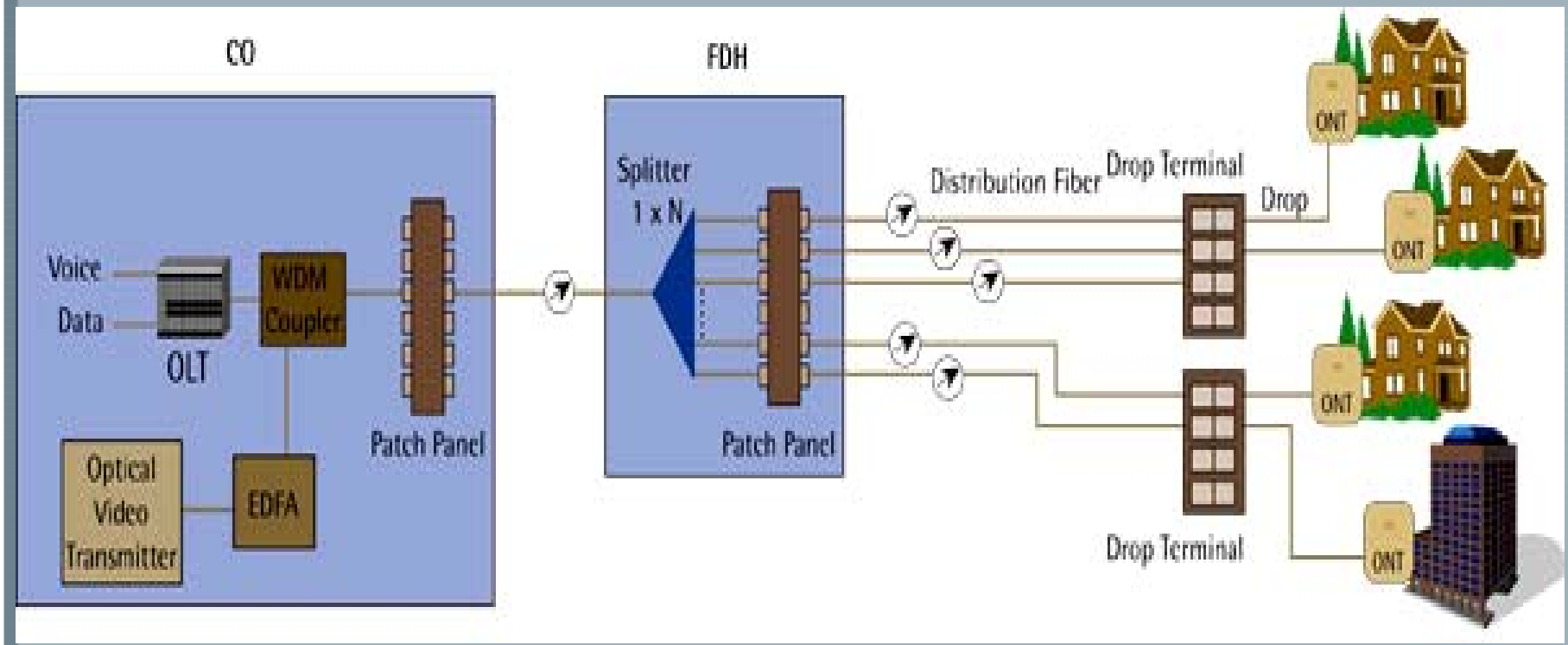
- Installation and Maintenance cost must be very low
- High volume
- High reliability (911 emergency calls)
- Maintenance is carried out by non-fiber specialists **in difficult environments**

# Introduction: FTTx: SM or MM?

- A few years ago: foresaw MM for cost & reliability issues
- Since then: significant improvement in SM connectorization and cabling
- Long distances: MM not well suited

$\Rightarrow$ SM is the good choice

# Introduction:
# FTTx PON Example



# 1. Construction and Installation Testing

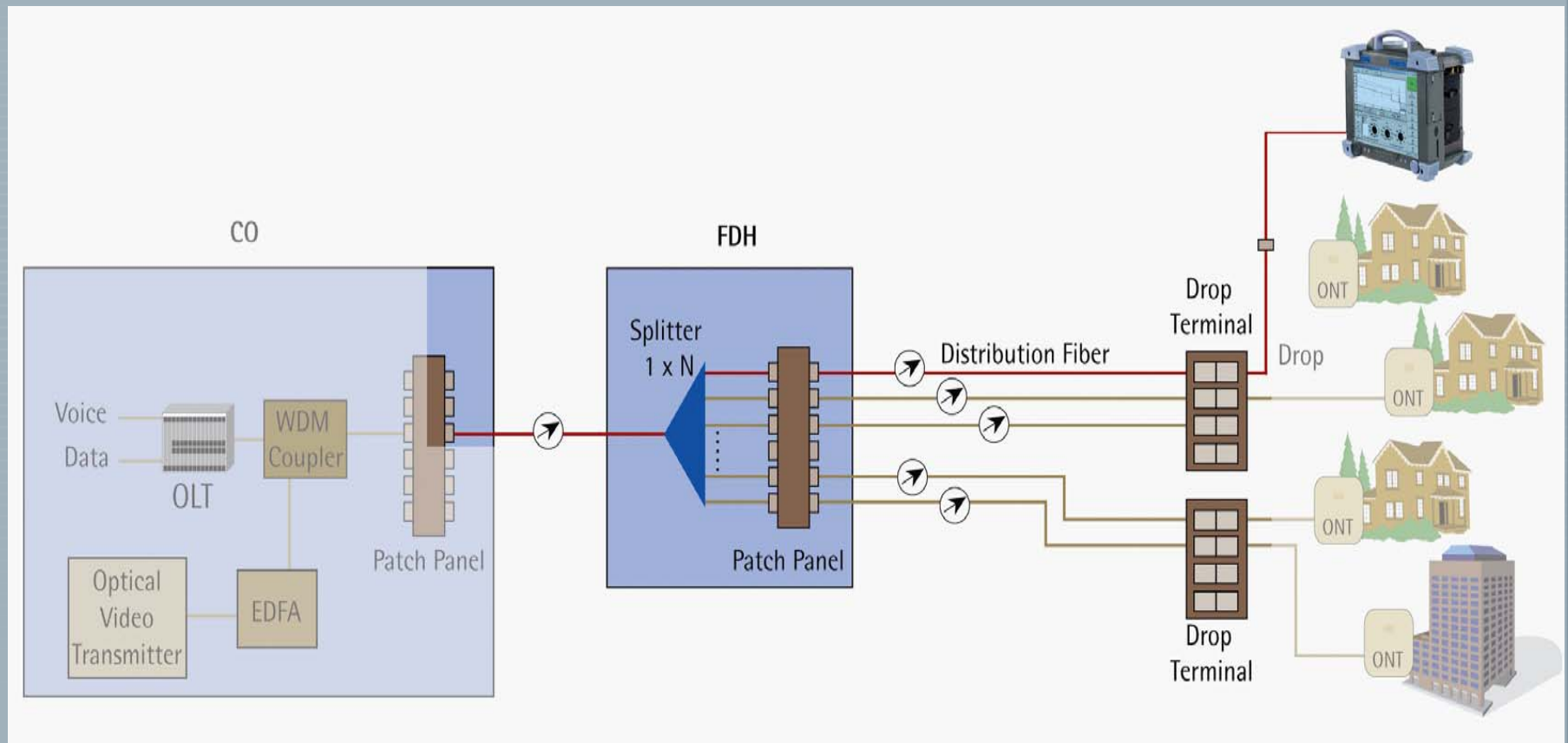
## Network installation tests

A. Bidirectional optical loss and ORL measurement can be done using:
   - Optical Loss Test Sets (OLTS) at 1310 nm, 1490 nm and 1550 nm

B. Fiber characterization can be done using:
   - PON-optimized OTDR at 1310 nm, 1490 nm and 1550 nm

# B. Fiber Characterization:
## OTDR Testing – Where to Test?

## Drop Terminal (or ONT) to CO (if spliced)



# B. OTDR Testing through a 1x32 Splitter

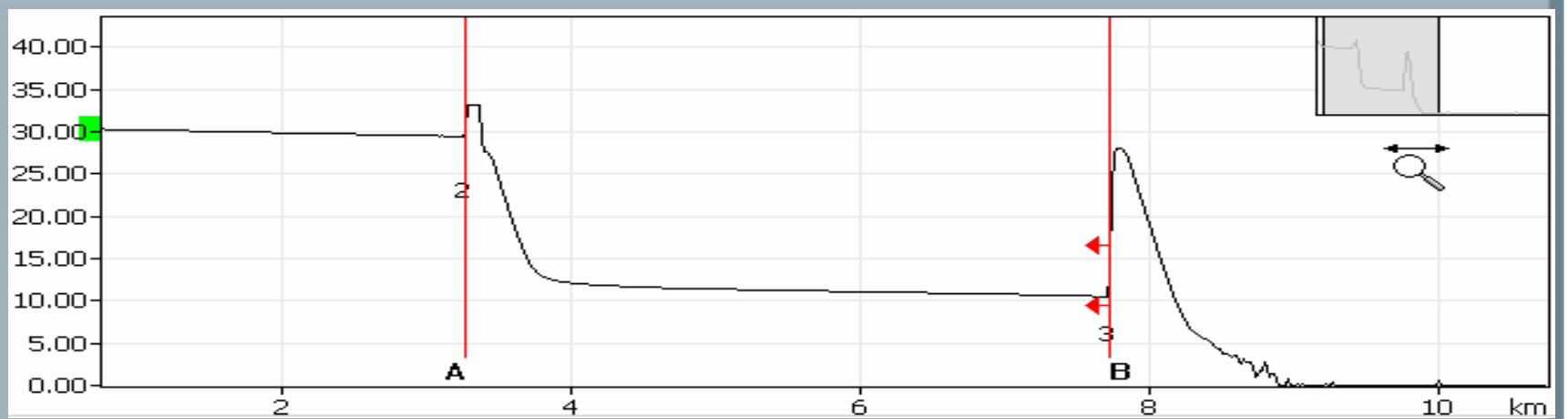
## Required OTDR characteristics for testing PONs

- High dynamic range (exceeding the PON loss budget)
- Short dead zones (for closely spaced events)
- Triple-wavelength testing (1310 nm, 1490 nm and 1550 nm)
- Also need: Good linearity and **eliminated long-term recovery**
- Configurable settings for PONs (e.g. end-of-fiber threshold)

# Testing Through a 1x32 Splitter

## Standard OTDR:


## PON-Optimized OTDR:



# Why is it so Important to Measure Reflections in Analog CATV Systems?

Signal type:

- Amplitude Modulation Vestigial Side Band (AM-VSB) transmission

Cause of potential problems:

- Localized reflections (as low as -55 dB)
  - Even though total ORL can be 32 dB

Problem:

- Multipath interference (MPI), ⇒ ghost images

Testing method:

- Only **way to verify** that each connection in the network meets **this requirement of -55 dB is to use an OTDR**

⇒ **APC** Connectors are required

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# 2. Service Activation Testing and Troubleshooting

## Technical challenges

I. Combined wavelengths on downstream signal (cannot use optical spectrum analyzers (OSAs))

II. Measuring the 1310 nm upstream data (emitted only when polled)

III. Measuring a sparse stream of data

# Technical challenge I

## Combined wavelengths on downstream signal

- Two separate signals at different wavelengths and powers; e.g,
  - 1550 nm analog CATV: 13 dBm
  - 1490 nm 622 Mb/s: -7 dBm
- A standard power meter: ~ 13.04 dBm (the combined power)
- No way of telling how much of 1490 nm or 1550 nm signal

## Preferred Solution: 2 separate detectors with filters

- To measure 1490 nm:
  - Filtering out the 1550 nm, high rejection required for analog video
- To measure 1550 nm:
  - Filtering out the 1490 nm is also important, especially for digital video

# Technical challenge II

Measuring the 1310 nm upstream data (same fiber, reverse direction)

- G.983.3: 1310 nm silent unless polled by 1490 nm
- OLT-ONT communication must be established
- Cannot use standard power meter

**Solution :**

**Use low-loss coupler in a “PON” power meter (coupler included in the calibration)**

# Technical challenge III

Measuring a sparse stream of data

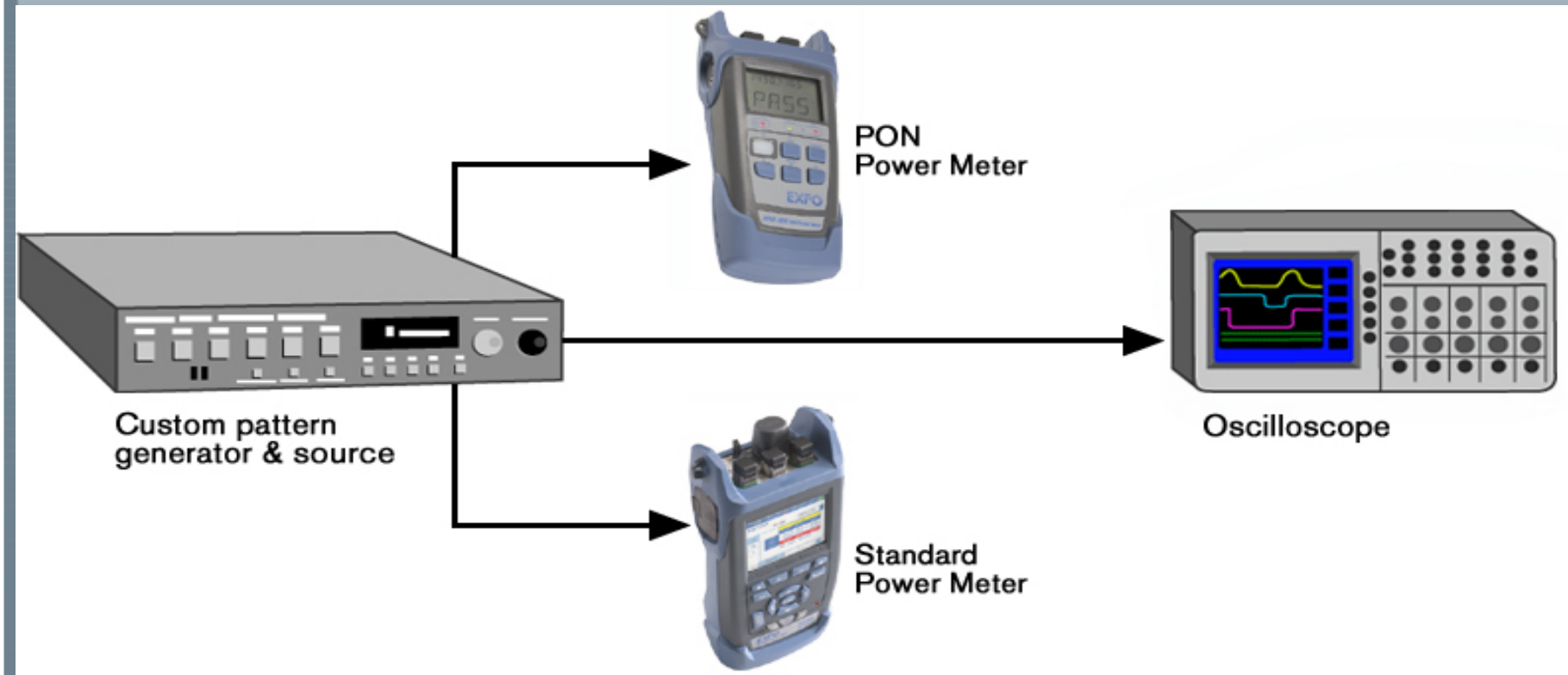
- ONT transmits only during predetermined time slots
- ONT could only reply to the OLT with a single cell every 100 ms (a cell lasts ~ 682 ns at 622 Mb/s)
- Equivalent duty cycle: ~ 0.0003 % (-55 dB)
- Standard power meter would not accurately reflect the power

**Solution:**

**PON power meter detecting the presence of a cell**

# 2. Service Activation Testing and Troubleshooting

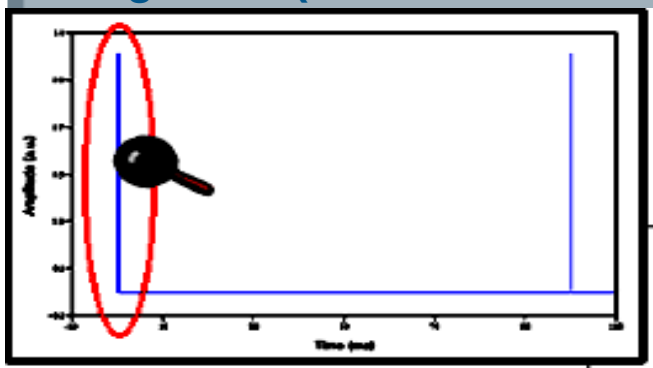
## Experiment: Measuring a sparse stream of data

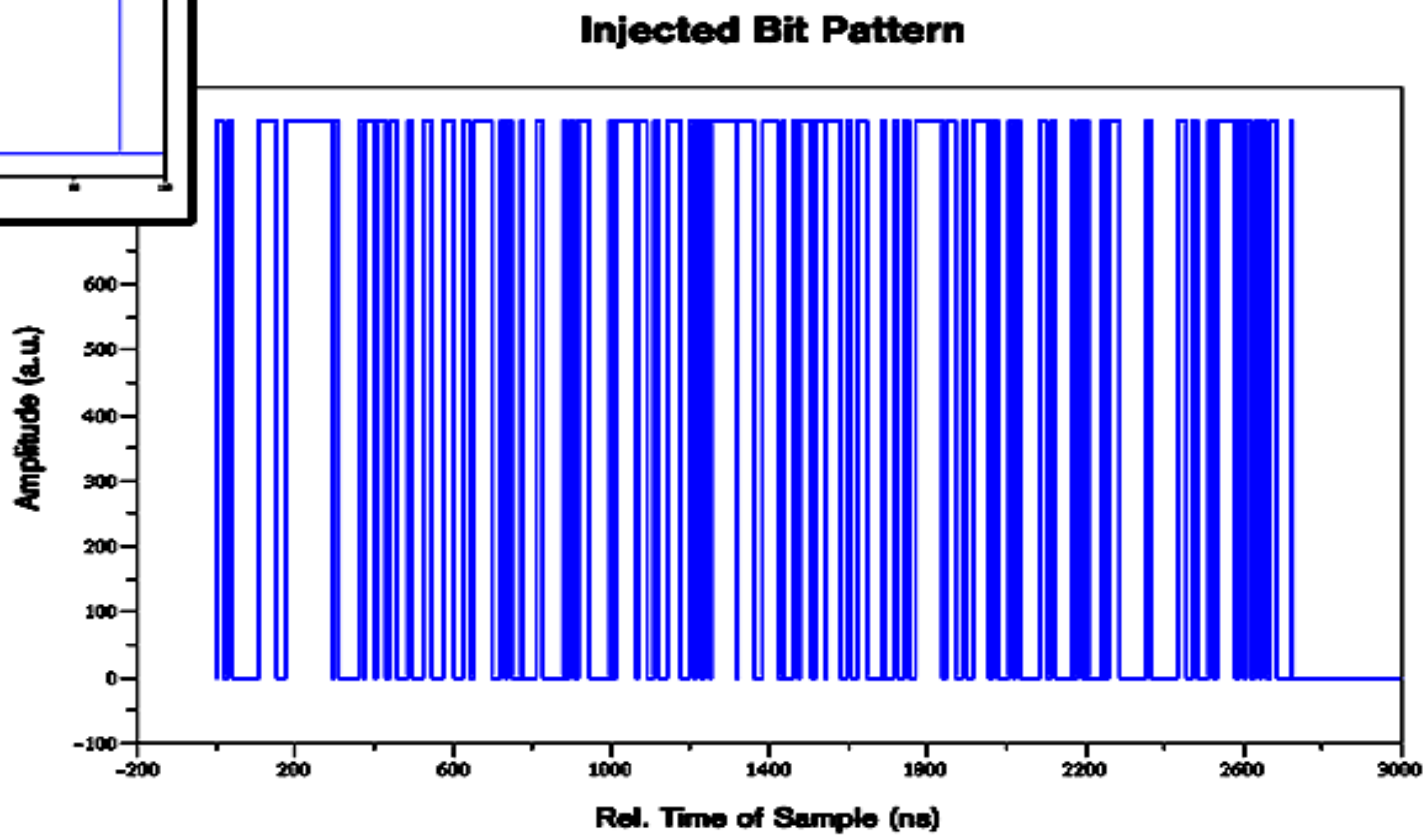


# 2. Service Activation Testing and Troubleshooting

## Experiment: Measuring a sparse stream of data

**Single cell (scrambled data ~ 50 % duty cycle, 2.7 µs wide @ 155 Mb/s) per 100 ms**





# Experiment: Measuring a sparse stream of data

**Results for the selected patterns at 1310 nm**

| Case | PON power meter | Standard power meter |
|---|---|---|
| | (dBm) | (dBm) |
| Continous (10 MHz) | **-2.9** | **-3.0 (Ref)** |
| **155 Mb/s** | | |
| 1 Cell / Frame | **-2.8** | **-20.7** |
| 1 Cell / 100 ms | **-3.6** | **-49.9** |
| **622 Mb/s** | | |
| 1 Cell / Frame | **-2.9** | **-26.7** |
| 1 Cell / 100 ms | **-3.7** | **-55.5** |
| | | |
| Max. deviation (dB) | **-0.7** | **-52.5** |

**Conclusion: PON power meter is essential**

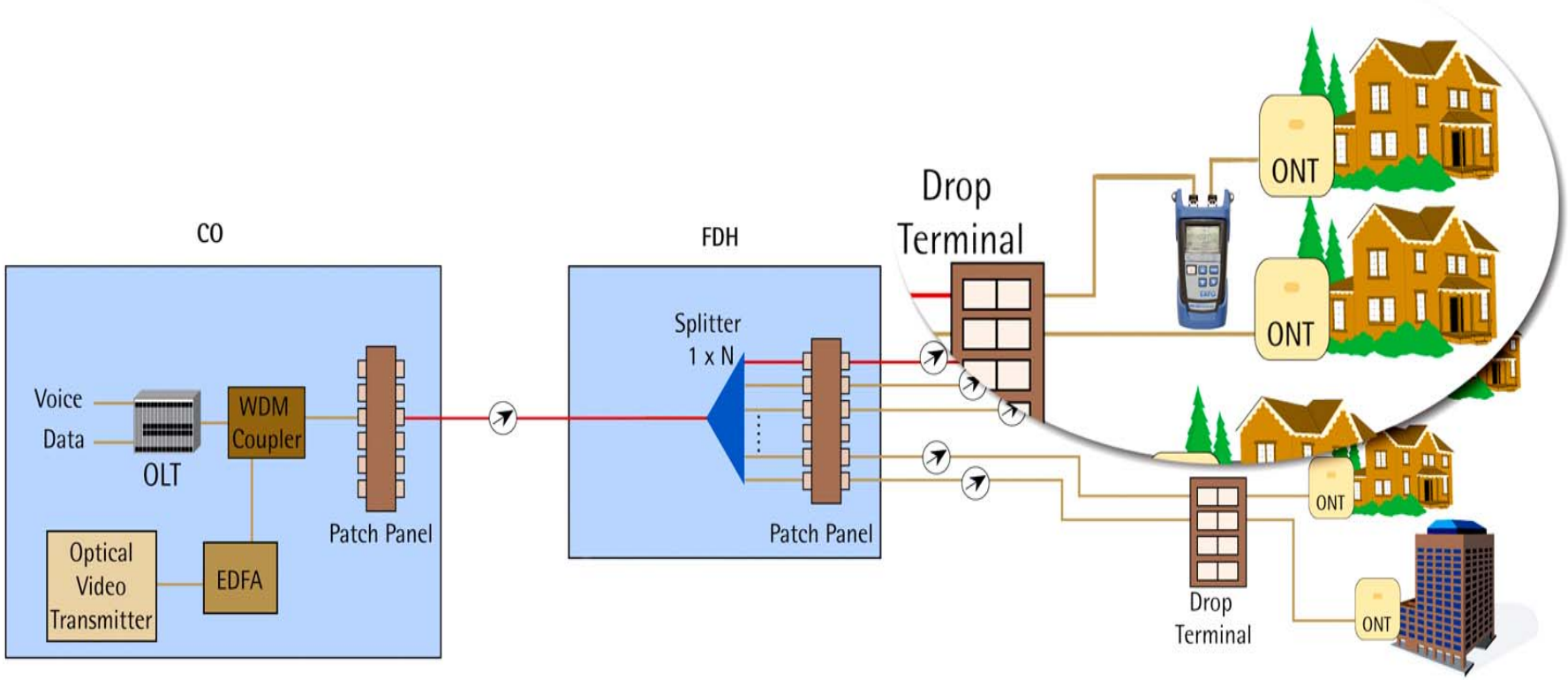
# 2. Service Activation Testing and Troubleshooting

## Summary of the specific requirements of PONs

a) Measure power of each wavelength
b) In a single operation
c) Allow OLT-ONT communication
d) Sufficient accuracy
e) Cover all standards power ranges
f) Insertion at any network point

# 2. Service Activation Testing and Troubleshooting

## PON power meter is inserted at the ONT



# Conclusion: New Metrology Issues

**Need to measure:**

- Loss and ORL / reflectance
  - at 3 wavelengths
  - through high-loss splitter
- Power of each of the wavelengths (at low-cost)
- Power of source that emits only if polled
- Power of a sparse stream of data

⇒ **FTTx requires dedicated T&M equipment**

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# Questions?